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Development of the Program System ECCES for Calculating Environmental Consequences from Energy Systems Status Report

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September 1984

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DEVELOPMENT OF THE PROGRAM SYSTEM ECCES FOR CALCULATING ENVIRONMENTAL CONSEQUENCES FROM ENERGY SYSTEMS. STATUS REPORT

Torben Petersen

Abstract. This report describes the status of the development of the ECCES program system. The ECCES system is intended to predict environmental impacts from a given energy production scenario in a given geographical area.

Presently ECCES can follow transport and transformation of selected airborne pollutants (Cd, SO_2, NO_x) from sources via dispersion in the atmosphere and deposition on the ground to uptake in selected crops.

The ECCES system contains submodels for dispersion and deposition, soil chemistry, and uptake of ions in crops. These models are summarized in the present report and a few examples of calculations are shown.

EDB descriptors: ACID RAIN; ACIDIFICATION; AIR POLLUTION; COMBUSTION PRODUCTS; COMPUTERIZED SIMULATION; CROPS; DEPOSITION; DISPERSIONS; E CODES; ENVIRONMETAL IMPACTS; ION EXCHANGE; POINT POLLUTANT SOURCES; POLLUTANTS; SOIL CHEMISTRY; UPTAKE.

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September 1984
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Danish summary. Denne rapport beskriver status for udvikling af programsystemet ECCES. ECCES skal kunne beregne miljømæssige konsekvenser af et givet energiforsyningssystem inden for et givet geografisk område.

I sin nuværende form kan ECCES beregne transport af udvalgte luftbårne forurenende stoffer (Cd, SO_2, NO_x) via spredning i atmosfæren, deposition på jord og planter, vekselvirkning med jordbundens kemiske processer og optag i udvalgte afgrøder. ECCES indeholder delmodeller for spredning i atmosfæren, deposition, jordbundskemi og planter. Disse modeller er beskrevet kort, og der er vist eksempler på beregninger med modellerne.

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1. INTRODUCTION

This report intends to describe the state of development of the ECCES program system which is designed to predict environmental impacts from a given energy production scenario in a given geographical area for a period of time.

In its ideal form, the model should be able to predict environmental impacts in a very broad sense such as human health effects, impacts on agricultural production and forests, and detrimental effects on man made structure (corrosion).

All impacts should be calculated based on values averaged over one or several months for concentrations of pollutants in the environment and doses experienced by human beings. Thus high concentration events will not be directly included.

It is realized that such a model have to consist of many submodels describing processes of which knowledge in some cases is sparse or non-existent. Therefore, a part of the work will be to find measures of environmental impacts which can be calculated with a reasonable confidence in the quality of the results. It will also be an important part of the presentation of results to state the uncertainty of these.

2. SUMMARY STATUS OF THE PROJECT

2.1. The program system

In the present stage of the project a model which follows the transport and transformation of airborne pollution from the source via dispersion in the atmosphere and deposition on the

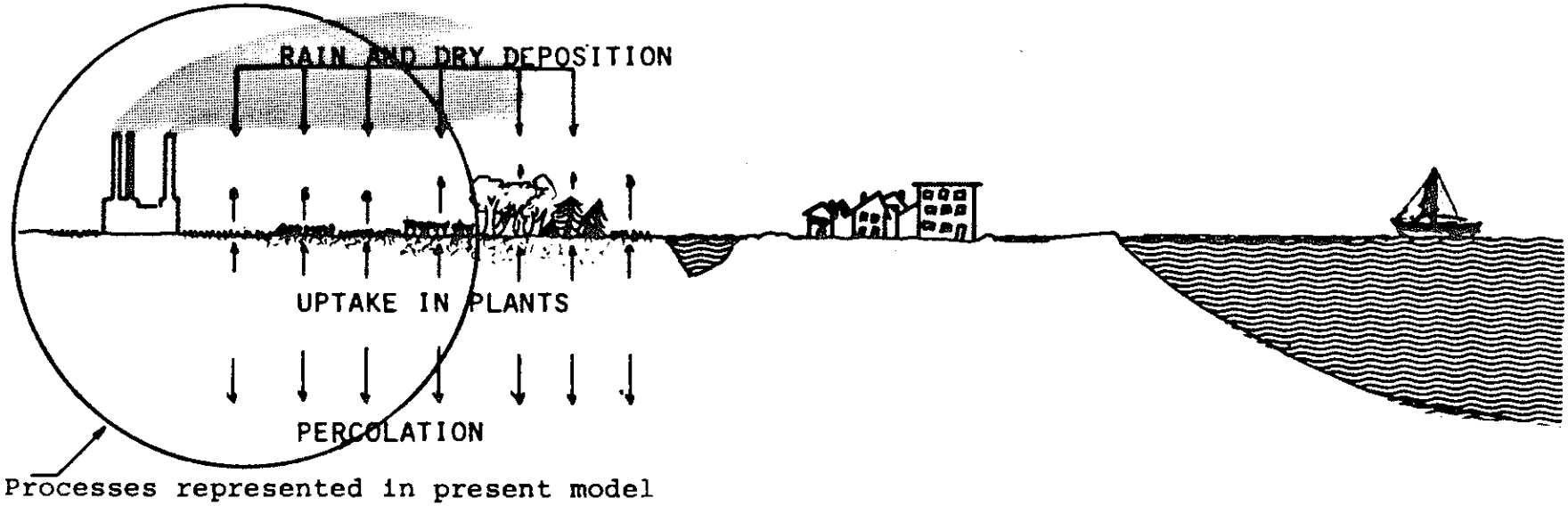
RAIN AND DRY DEPOSITION
UPTAKE IN PLANTS
PERCOLATION
Processes represented in present model

Fig. 1.

ground, to uptake in selected crops, has been developed as indicated in Fig. 1. Aquatic systems, nonagricultural areas and built up areas are not included.

Sources for pollution may be point sources such as power plants or area sources such as built up areas with individual heating. As pollutants are chosen, in a first example, Cd and SO_2, the latter representing a pollutant undergoing chemical reaction in the atmosphere. The geographical area (see Fig. 2) to be considered in the scenario will be the island of Zealand (on which Copenhagen is situated). The scenario is defined by giving the emission and position of the pollution sources on Zealand and a description of those areas within Zealand in which the environmental impacts should be studied. A description of an area includes such data as sizes of areas in which certain crops are grown, sizes of built up areas, data for soil properties where crops are grown, population densities, etc.

The model presently in existence thus contains submodels for atmospheric dispersion and deposition, soil chemistry, uptake in selected crops, and a main program which has a description of the geographical area and positions of sources in it and which can handle data transfer between the submodels.

In this first stage, air concentration of pollutants, concentration in the plants and change in acidity of the soil will be used as measures for the environmental impact of an energy production scenario.

2.2. The submodels

This report gives an overview of the ECCES program system. The submodels are only briefly described so as to give an idea of the mechanisms taken into account. Detailed descriptions are found in reports referenced in the respective sections.

The degree of detail in representing physical and chemical processes in the submodels is a compromise. On one side the

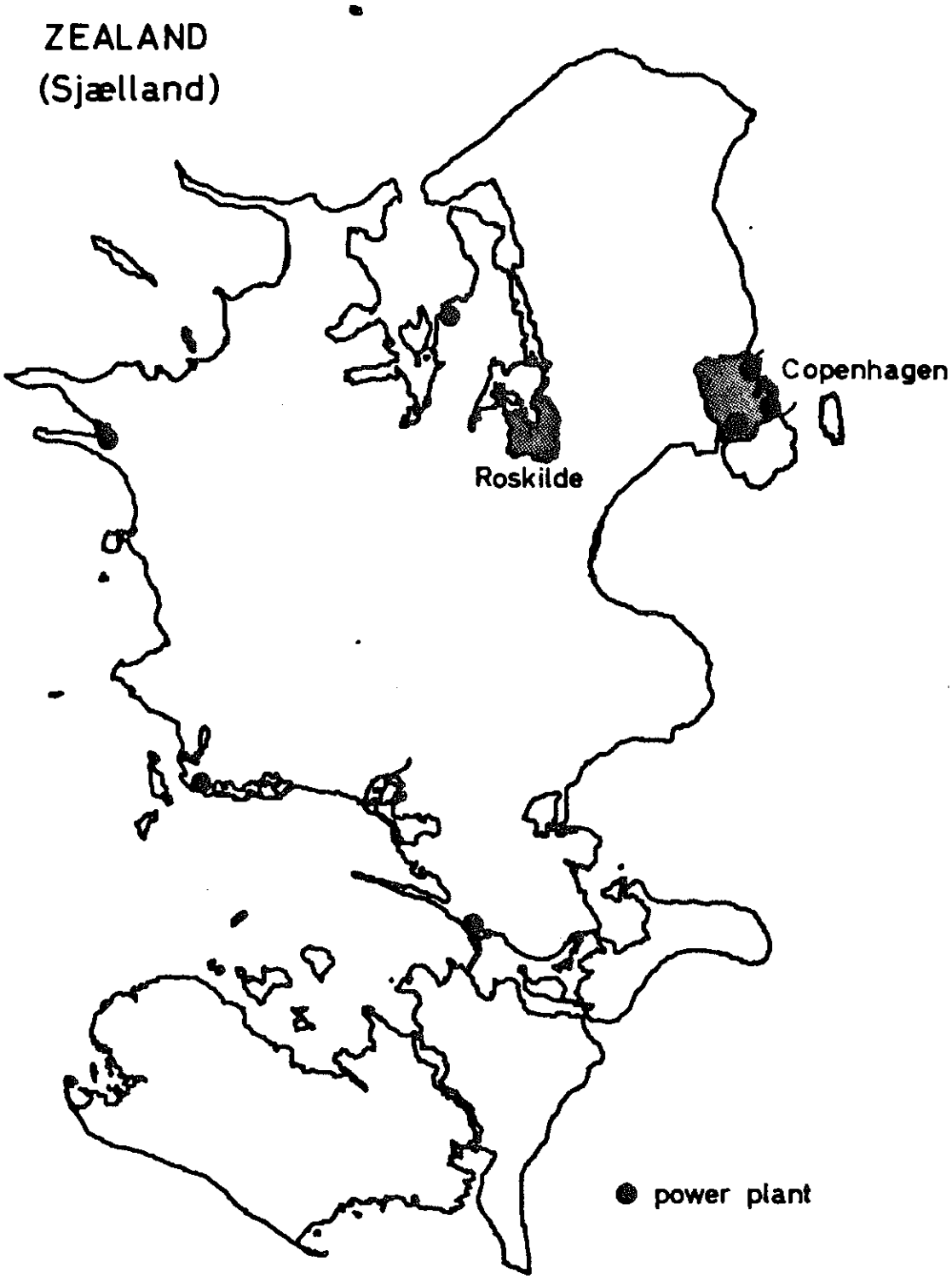

Fig. 2. Geographical area used in scenario.

models should give realistic representation of the processes. On the other side there are limitations such as a demand for fairly short computer time, ease of use, etc.

The aim is to include details of the processes to such a degree that the effects one wants to investigate are modelled. In addition, models for which data is available presently or may be expected to be available in the not too far future should be selected.

Only few calculations are shown. They are meant to illustrate how the models work. The parameters used for the models are chosen as realistic as presently possible. However, a systematic verification of the models have not yet been made and much data has still to be found. The reported results should be seen in this light.

2.3. Preliminary conclusions

The complexity and size of the program so far developed does not exceed what is fairly convenient to handle for practical purposes. This conclusion is still expected to be valid when the model is extended to include more submodels.

It appears to be useful to have a model which combines existing knowledge in several areas. Especially when the model is easy to use for realistic scenarios. E.g. although very good dispersion models already exist, the dispersion part of the present model was used in an assessment of the effects of acid deposition by the Danish environmental authorities. The model was used because it was easy to use for a scenario containing several sources for airborne pollution. This will probably also be the case in other areas where models developed for research purposes exist. If the research model is inconvenient to handle, the use of a research model all through the many steps of a scenario calculation may be impracticable.

There will inevitably be uncertainties in results from the model due to approximations in the submodels and uncertainties in data. Even if such uncertainties turn out to be large in assessing absolute values, the model may be useful to estimate relative importance of factors which influence the environment. This could be the case f.ex. when assessing the relative importance of heavy metals from power plants and from fertilizers.

3. PROGRAM STRUCTURE

As indicated in the introduction airborne pollution may be followed from sources (power plants etc.) to uptake in plants. The program structure is shown in Fig. 3. (Christensen, 1984).

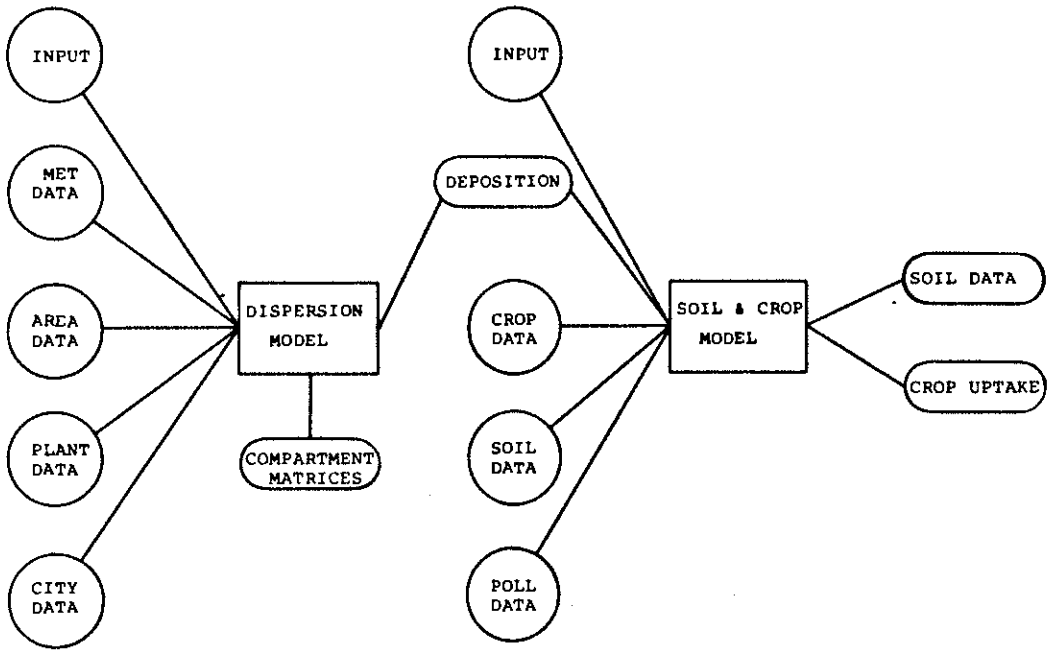

Fig. 3. Program structure.

A key feature of the program is the description of the geographical area under consideration relative to a rectangular coordinate system. The positions of sources as well as receptor points are given in this system.

In the time domain the program operates in discrete time steps, typically a year or a fraction of a year. However, each of the submodels may operate with different time steps in the same run as mentioned in more detail later in this report.

In designing the program structure care has been taken to obtain as large a flexibility as possible. It is intended that program modules for submodels may easily be replaced. During development of the program it is also ensured that most of the submodels shall exist as separate programs.

Thus dispersion calculations alone may be carried out where input are emissions and positions of sources in a geographical area. The results are concentration in air and amount of deposition of pollutants in selected points.

In the same way the soil chemistry and plant models may be run alone to show changes in soil chemistry and uptake in plants when ions and water are added to the surface of the soil.

4. MODEL FOR ATMOSPHERIC DISPERSION AND DEPOSITION

4.1. Dispersion model

The model for atmospheric dispersion is based on a plume model (a modification of the Gauss model) (Højerup, 1984). Dispersion and deposition are calculated for average meteorological conditions, that is, for atmospheric stability, wind direction and precipitation are used average values for longer periods (typically one year). The dispersion is calculated in twelve 30°

sectors, thus covering all directions. Weather characteristics in each direction are obtained as the appropriate average values from the meteorological data.

Deposition of a specific pollutant is characterized by a deposition velocity. The model can handle a pollutant emitted in one chemical form and then transformed into another chemical form. The transformation is modelled by ascribing a half life to the emitted pollutant. Deposition velocities may be different for the two chemical forms of the pollutant. This design of the model has been selected since it should be able to model dispersion phenomena associated with SO_2 and NO_x.

4.2. Area sources

Pollution from traffic, houses, etc. is usually characterized by being emitted at low heights (< 10 m) and being emitted from a large number of more or less uniformly distributed sources.

For such sources it is assumed that emission is uniformly distributed throughout the area in which they are situated. All sources are assumed to have the same emission height. This area source is then approximated by N fictitious sources, one situated in the "centre of mass" of the area and the rest situated equidistant on a circle with centre coinciding with the centre of mass for the area and radius

$$R' = \tfrac{1}{2}(R+R/\sqrt{N})$$

where R is the radius of a circle which has the same area as the area source (see Fig. 4).

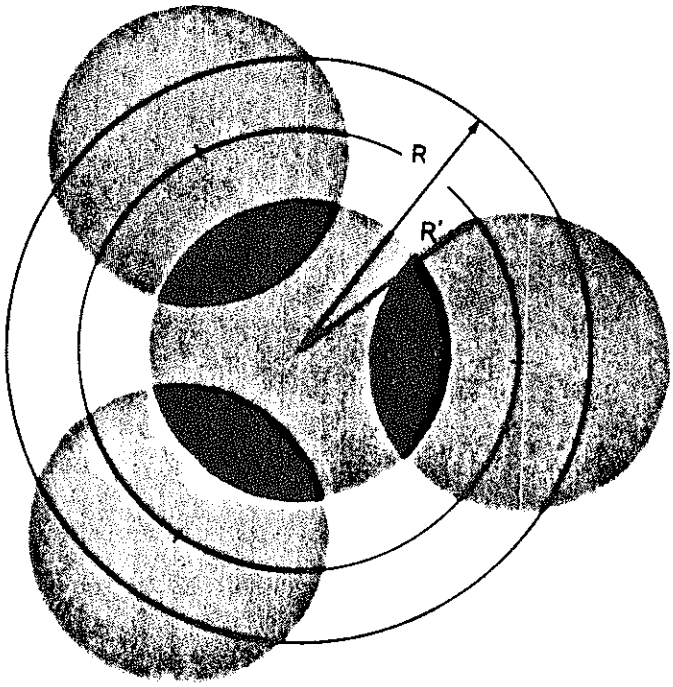

Figure 4. Fictitious sources to represent an area source for airborne pollution.

Each fictitious source has source strength 1/N of the total area source. N may have any value, however, N=4 appears to be sufficient.

Air concentration and deposition of pollutant in a point outside the source area are now determined as the sum of contributions from the N fictitious sources. The contribution from each source is calculated based on the distance between source and receptor point and the direction from source to receptor point.

Inside the source area the same procedure is followed except for the contribution to a subarea from the subarea itself. The latter is calculated as the average inside the subarea circle from the fictitious source in the centre of the subarea. The averaging is accomplished by dividing the circle in 5 annuli.

4.3. Transfer matrix

If a scenario contains many source points and many receptor points computer time may be large, especially if a pollutant with chemical transformation is considered. Instead of using actual source strengths one may use unity source strenghts for all sources. A transfer matrix is then calculated, which gives air concentrations and depositions in all receptor points from all source points. Deposition and airconcentration for any scenario with the same source and receptor point positions and the same pollutants may then be calculated at very low computing cost.

4.4. Examples of calculation with the dispersion model

The dispersion model has been used in connection with an assessment of the impacts of acid precipitation in Denmark carried out by the Danish environmental authorities. In this investigation the model was used to judge relative importance of acid deposition from power plants, district heating systems and area sources.

As an example of this type of use of the model, table 1 shows results of calculations of air concentrations and deposition of SO_2 at a receptor point on Zealand (Fig. 5). Sources are existing power plants as they are actually situated with an emission of SO_2 estimated as realistically as possible for 1980. In addition area sources representing built up areas on Zealand are taken into account. Emissions are again estimated as re-

alistically as possible based on knowledge of average power consumption pr. capita and the number of inhabitants in the areas considered.

Fig. 5. Geographical area for dispersion calculation. County borders shown.

Note the very large contributions from the area itself (D) and the local plant (plant no. 8 in the table, a refuse disposal plant), despite the modest source strengths.

Table 1. Contributions to air concentration and deposition rate of sulphur (as SO_2 and SO_4) in the municipal area of Roskilde from all power plants on Zealand and from all other sulphur-emitting activities on Zealand.

From Plant no.	Emission rate kg/sec.	Air concentration Microgram/m^3	Deposition rate Gram/m^2/year
1	0.568	0.543	0.137
2	0.104	0.232	0.059
3	0.027	0.016	0.004
4	0.141	0.123	0.030
5	0.112	0.125	0.031
6	0.105	0.144	0.035
7	0.082	0.121	0.030
All power plants on Zealand	1.139	1.304	0.326
8	0.0022	0.134	0.034
Area			
A	0.540	1.319	0.328
B	0.143	0.226	0.056
C	0.056	0.643	0.162
D	0.022	1.994	0.492
E	0.122	0.487	0.119
F	0.114	0.075	0.018
All area sources on Zealand	0.997	4.744	1.175

5. SOIL CHEMISTRY AND CROP MODELS

5.1. Soil Chemistry Model

The soil chemistry model (Brodersen, 1984) describes the interactions between the ions added to the soil chemistry system by rain, dry deposition of airborne material, fertilizers, etc.

The soil may be divided into up to 5 layers. Each layer is treated as a homogeneous compartment. A compartment contains solid material, soil liquid (water) and air.

The vertical movement of water through the soil layers is described by a very simple hydrology model. Each layer is assumed to be able to contain a maximum amount of water. A minimum amount of water is not available for root uptake. In the uppermost layer water may be added by rain or irrigation in known quantities. The amount of evaporation is assumed to be known as well. Water uptake in roots of crops is calculated by the plant model (see sect. 5.3). If the amount of water added to the soil layer by these processes exceeds the amount required to fill the layer to its maximum inventory, the exceeding water is assumed to percolate to the following layer. The layers beneath the uppermost layer are treated in the same way, except that direct evaporation is assumed zero.

For each compartment or layer equilibrium concentrations of ions in solution and ions adsorbed to the solid material is calculated. The adsorbtion is associated with the ion exchange capacities of the solid material.

Cation exchange is described by a permanent exchange capacity associated with electrical charges on clay particles, and a variable exchange capacity, associated with hydrated oxides of Al, Fe, Mn, and organic material. The variable cation exchange capacity is dependent on pH.

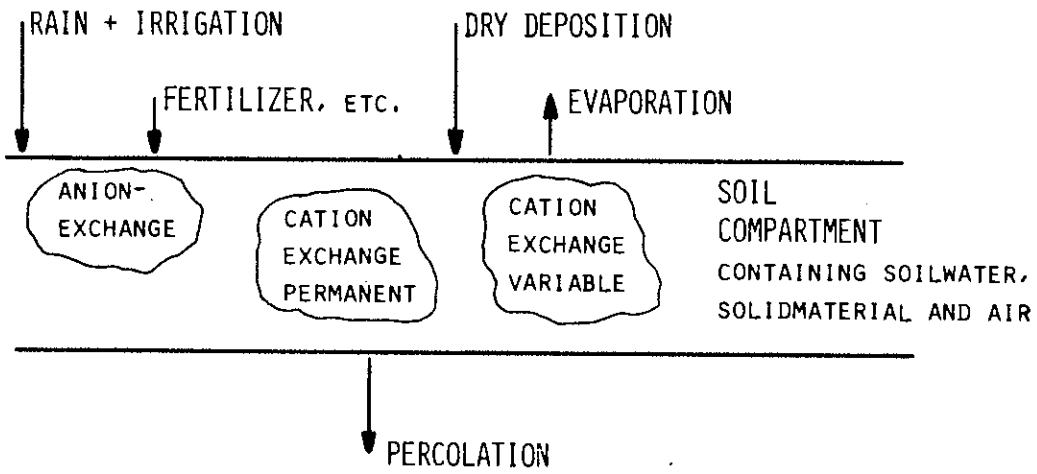

Fig. 6. Soil compartment.

The model can also take into account that the anion SO_4^{--} in some soil types may be adsorbed on hydrated oxides of Al, Fe, and Mn. The adsoption is described as a pH dependent Langmuir equation.

The ions and chemical equilibria considered in the model are shown in Table 2.

Only one trace element (Cd) is shown in Table 2, but other trace metals can easily be added to the system.

Ion concentrations are calculated from a set of mass balance equations. The equilibrium between ions in solution and on the permanent ion exchanger is calculated from the so called lime potential, which accounts for the partial covering of the permanent ion exchange capacity by aluminium at low pH. The system takes chemical equilibrium or carbonate-bicarbonate, the solubility of lime ($CaCO_3$) and gypsum ($CaSO_4\ 2H_2O$) into account. The program also calculates the concentration of aluminium.

Table 2.

Solid Compound	Solution	Adsorbed
$CaCO_3$	Ca^{++}, Mg^{++}, Na^{+}	CaX, MgX
$CaSO_4 2H_2O$	K^{+}, NH_4^{+}, H^{+}	NaX, KX
		NH_4X, HX
	Al^{+++}, Cd^{++}	
$Al(OH)_3$		CdX
	SO_4^{--}, Cl^{-}, NO_3^{-}	
	HCO_3^{-}, CO_3^{--}	SO_4X

5.2. Microbiological Processes

The soil chemistry model as described above only contains inorganic processes (except ion exchange mechanisms which may be associated with organic substances). However, to give a more realistic picture of the chemistry of the soil, microbiological processes have to be taken into consideration. Microbiological processes are amongst other things responsible for decomposition of dead organic material such as plants and animal material. Such processes have strong influence on the behaviour of especially the nitrogen, the sulphur, the phosphorus, and the carbon cycles. An extension of the soil chemistry model which takes microbiologically induced chemical transformation of these four elements into consideration has been developed, but is not yet incorporated in the program. Therefore it shall not be described here.

This part of the model is reported in (Mortensen 1984 a).

5.3. The Crop Model

Crops growing on a soil will influence the soil chemistry by uptake of water, nutrients, micro nutrients and trace metals. Plants also form part of the pathway for certain elements, e.g. heavy metals, to animals and man.

The crop model included in the ECCES system has been set up to model these effects (Mortensen 1984 b). The intention is to calculate the chemical effects on the soil upon which the plant grows and the amount of trace element taken up by the plant. The model is not intended to model plant behaviour as such, that is, growth etc.

The basis for the plant model is a table which has the above ground biomass production and the associated water uptake from the soil tabulated on a monthly basis for the growing season. In the same table evaporation from soil surface is given. These values are used for the hydrology model in the soil chemistry model.

The uptake of nutrients and trace elements via the root system is assumed to be proportional to the uptake of water multiplied by concentration of the ions in the soil water. The proportionality constant may be different for different crops and different ions. When ions are taken out of the soil system by plants, electroneutrality is obtained by adding or subtracting H^+ (see Fig. 7).

Since concentrations of ions will be different in different soil layers and since the root system will be distributed through the soil layers, the crop model assumes the root system to be divided into three root zones. These are horizontal layers which may or may not coincide with soil layers (Fig. 8). The fractions of total water uptake from each root zone are input values. The uptake of ions from each root zone is calculated from concentration in the soil water of the root zones.

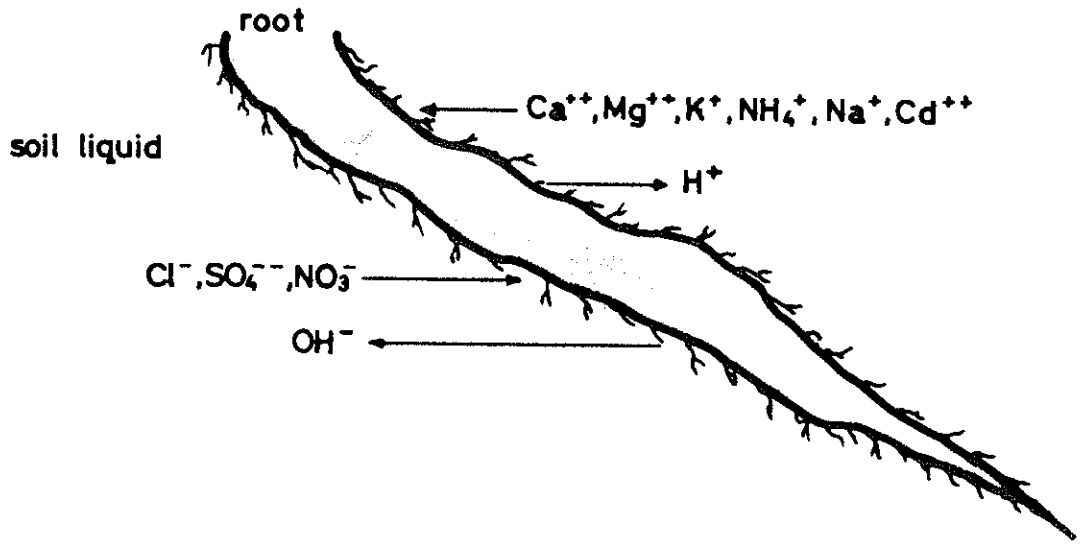

Figure 7. Uptake of nutrients and pollutants from soil liquid.

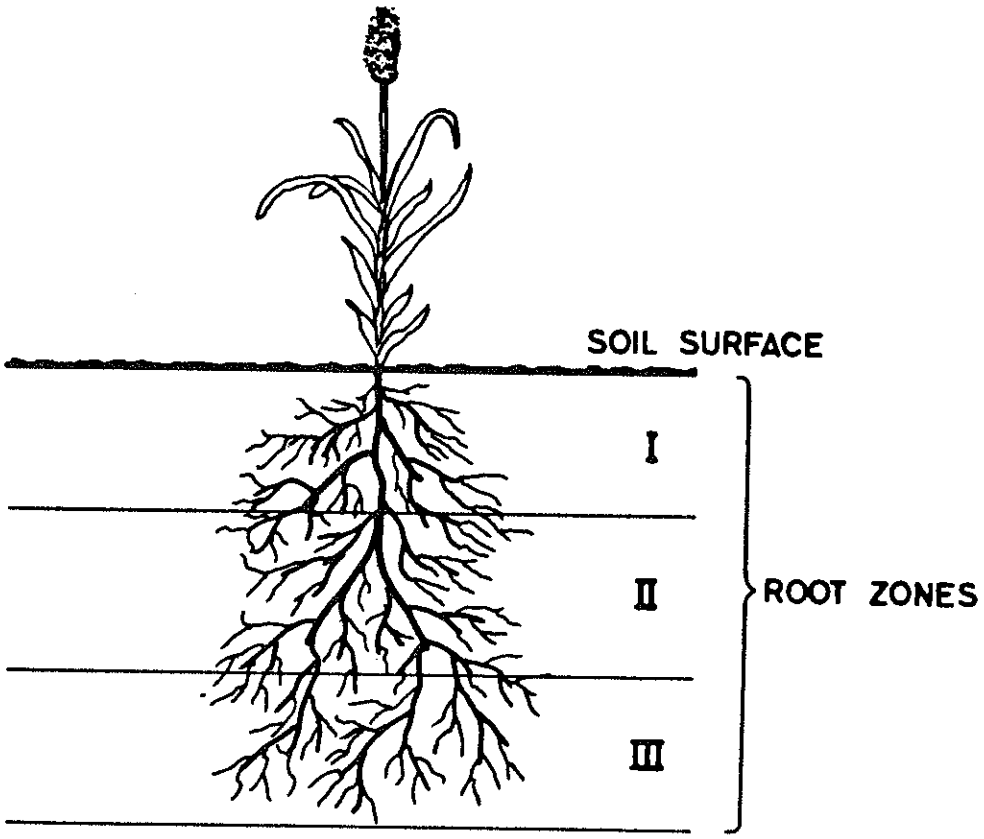

Figure 8. Root distribution.

Materials deposited on plant leaves may also be taken up by the plants. This uptake is calculated by:

uptake via leaves =

deposition x(1-exp(biomass of plant x constant)).

From the above it appears that time steps for the combined soil chemistry-plant model are fixed at one month. Input from the dispersion calculations of deposition on soil and plants are normally calculated for time steps not shorter than 3 months. The models are simply matched by calculating the monthly average deposition from each dispersion timestep and then using this for the corresponding timestep of the soil chemistry-plant model.

5.4. Examples of calculation with the soil chemistry and crop models

To show some of the mechanisms which can be represented by the soil chemistry-crop model a simple but rather artificial example is shown.

Uptake of Cd in barley from a fairly characteristical clay soil is calculated. The soil is exposed to a rain with a concentration of $1.3\ 10^{-9}$ Mol/l Cd^{++}, a concentration which is believed to be fairly characteristical for Danish conditions.

Two cases have been run. One with a rather acid rain (pH = 4) and one in which the rain is in equilibrium with CO_2 in the atmosphere (pH = 5.6). To start the calculation a Cd^{++} concentration of $7.5 \cdot 10^{-9}$ Mol/l and a pH of 7 were assumed in the soil water.

In figure 9 pH in soil water and concentration of Cd^{++} in the crop are shown.

The amount of rain was 60 mm/month. The period of time is 30 years.

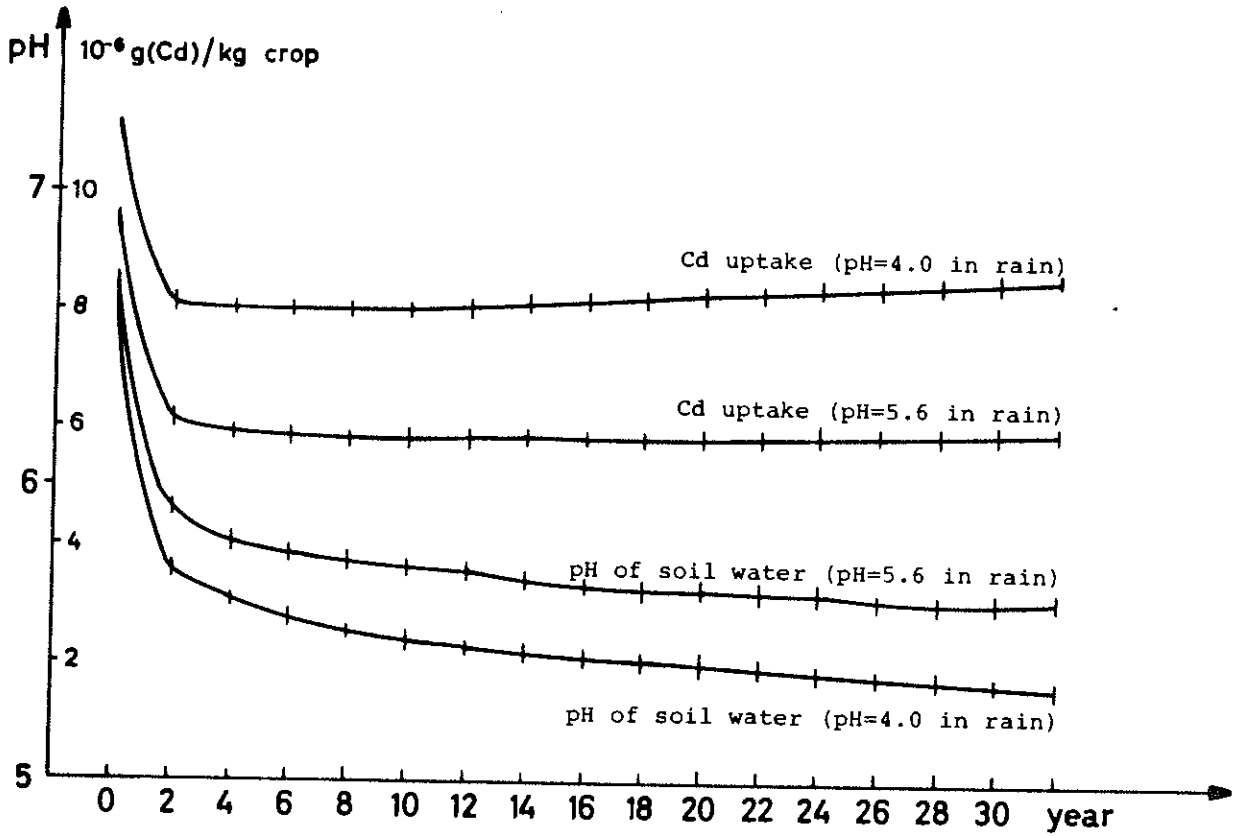

Fig. 9.

The figure shows the initial transition of pH and uptake of Cd^{++} as the soil water ajusts to the pH and Cd^{++} concentration of the rain.

It is seen that the low pH gives a higher uptake of Cd^{++}. This is due to the many more sites of the ion exchange material occupied by Al^{+++} in the low pH case. Thus at lower pH fewer ion exchange sites are available for adsorption of Cd^{++}. This causes a higher concentration of Cd^{++} in the soil water and as a result a higher uptake of Cd^{++}.

In both cases the uptake of Cd^{++} is seen to increase as pH drops.

6. DATA REQUIREMENT AND DATA STRUCTURE

6.1. Availability of data

It appears from the above descriptions of the models that many parameters are required for the models to give realistic results. Along with the development of the models some initial collection of data has been carried out (Mortensen, 1983), but a much more thorough search for data, sensitivity analysis and verification of models still remain.

However, during the work, care was taken to select formulations of models, the parameters of which were either available or could be derived from other available parameters, or could be estimated for Danish conditions from measurements in other countries, or might be expected to come forward as a result of future measurements.

It is obvious that one cannot expect all data needed for a model as the present to be available. Much data does exist and the present work should serve as a practical framework for collecting data from many sources, organize it in such a way as to make it suitable for overall investigations of environmental conditions and to identify areas where it is of importance to collect further data if such investigations are to be carried out.

It is always important to have a well organized and flexible data structure for computer models. The arguments above make it even more important to make the data structure flexible and logical, since one does not know during the initial development of the models what the final amount of data will be. F.ex., models are likely to change, requiring new parameters to be fitted into the data base or one may wish to extend the number of different soil types for which parameters exist in the data base, etc.

6.2. Data requirements

To explain the data structure which has been adopted an overview of the data requirements is given.

The geographical area which is considered in a scenario is described relative to a rectangular coordinate system.

The whole area is divided into subareas. The position of a subarea is given as the position of the centre of mass of the subarea. When source positions are known, distances between sources and areas where deposition takes place can be calculated by the program.

Since only the position of the centre of mass for a subarea needs to be known, the shape can be chosen freely. Thus the borders of subareas may be chosen to coincide with administrative borders. This makes the collection of information such as the amount of different crops produced, population within the area, etc. much easier.

In addition to position of the sources and the subareas a whole series of data is needed for both.

For the sources these data are types and amounts of emitted pollutants, chimney heights, etc.

For subareas data needed are such as total area, area for growing of each relevant crop, identification of types of crops, soil types etc.

The submodels, that is, dispersion model, soil chemistry and crop models also require a series of parameters.

6.3. Data structure

The above data is organized in the following manner.

The parameters for the submodels are grouped in files so that all information concerning a single pollutant is collected in one file. This file contains deposition velocities, rate of chemical transformation in the atmosphere, data concerning the behaviour of the pollutant in the soil and parameters for the rate of uptake in crops. Such a data file is given a number. This number should always be the same for a given pollutant.

In the same way, parameters characterizing soils and parameters characterizing crops are grouped in data files. Both the data files for soils and crops are given numbers which should always be the same in any scenario.

Data for sources and subareas are also collected in files with numbers attached to them. In these files f.ex. the types of pollutants emitted by a specific source are specified by giving the numbers of the relevant pollutants.

All these data files are permanently stored together with data files for weather as a data bank.

The data structure is illustrated in Fig. 10.

There will be data which may logically belong to more than one data file. E.g. characterization of uptake of a certain pollutant in a certain plant may either be considered a property of the pollutant or the plant. Such data is stored in order to give the largest flexibility when the data is used.

As the model is used for new scenarios the data bank shall expand. By keeping a cataloque which shows the identification numbers of pollutants, soil types, subareas, etc. one may go back and reuse already collected data for new scenarios without having to set up large amounts of input data.

If f.ex. one has run a scenario with Cd as pollutant one may run the same scenario with Hg as pollutant simply by changing the identification number of the pollutant. Provided data for Hg is present in the data bank.

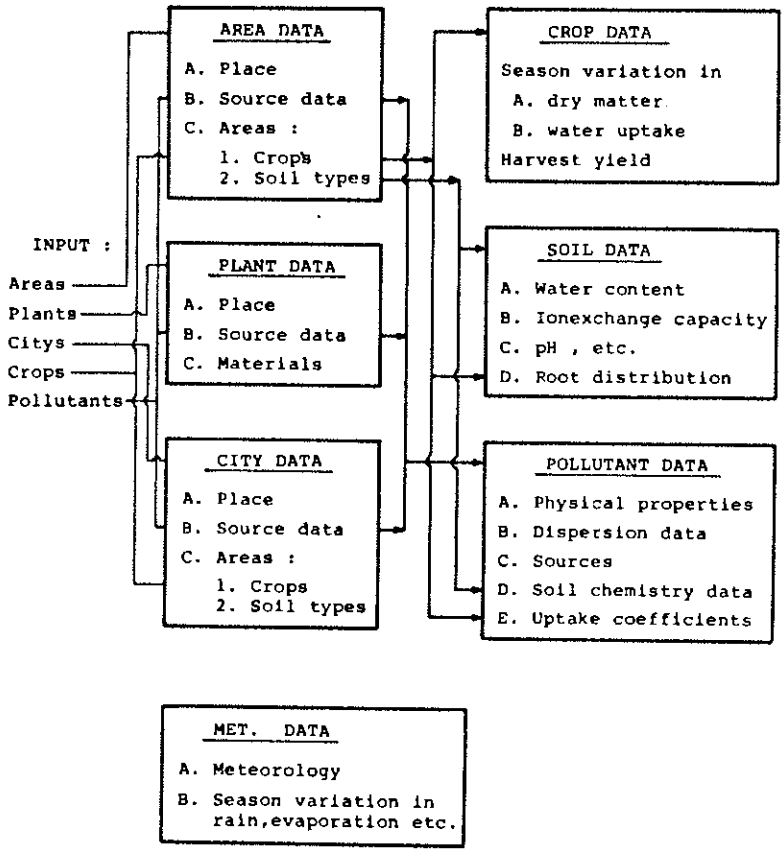

Fig. 10. Data structure.

7. PRESENTATION OF RESULTS

In the present model the impacts on the environment from an energy production scenario are expressed in terms of changes in soil chemistry and concentrations of selected elements in selected crops.

The results from the calculations are presented in tables (see Fig. 11). Irrespective of the time step selected for the calculation the table in Fig. 11 shall be printed for each year in the scenario. A table summarizes the impacts in one receptor area (e.g. a county). A receptor area is allowed to have up to

7 different soil types on which crops are grown and up to 10 different crops. 9 different pollutants may be treated in one scenario.

If a receptor area is defined to have n different soil types, the area on which each crop is grown is assumed to consist of n equally large areas each having one of the n different soil types.

The table then shows year and identification number and name of receptor area (county name).

In the next block of figures, the first column shows average air concentrations for each pollutant for the year in question. The next columns show concentration of each pollutant in each crop given as µg/kg of dry matter of crop. This is given for the crops harvested in the year in question.

In the following block, the first column shows average deposition for each pollutant in each crop for the year.

Since the model thus presently is concerned primarily with effects on agricultural areas, the effects of acid deposition in terms of change of pH in the soil is not expected to show in reality. For agriculatual areas one would expect pH to be kept constant f.ex. by adding $CaCO_3$.

To show the effect of acid precipitation, the soil chemistry model therefore automatically adds $CaCO_3$ to keep pH within specified limits. The accumulated amount of $CaCO_3$ to stabilize pH for the scenario is shown in the last line of the table.

As a last indication of the effects of acid precipitation a fictitious pH for each soil type in the receptor area are shown. These figures are calculated assuming no neutralization by $CaCO_3$ and that crops grown (grass) are not harvested.

TIME = 1987

AREA NUMBER : 2
IDENTIFICATION : 11112000
FREDERIKSBORG AMT

CONCENTRATIONS IN MICROGR./KG

POLLUTANT NO.	NAME	AIR CONC. MICROGR./M3	WINTER CEREALS	SPRING CEREALS	LEGUMES	POTATOES	SUGAR BEETS	OTHER BEETS	SEEDS	GRASS	GARDENING CROPS	OTHERS
1	SULPHUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	CALCIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	CADMIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	CHLOR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	POTASSIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	MAGNESIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	SODIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	AMMONIA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	NITROGEN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

QUANTITIES IN CROPS IN T/YEAR

POLLUTANT NO.	NAME	DEP. RATE G/M2/YEAR	WINTER CEREALS	SPRING CEREALS	LEGUMES	POTATOES	SUGAR BEETS	OTHER BEETS	SEEDS	GRASS	GARDENING CROPS	OTHERS
1	SULPHUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	CALCIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	CADMIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	CHLOR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	POTASSIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	MAGNESIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	SODIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	AMMONIA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	NITROGEN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

ACIDITY :

PH OF SOIL TYPE (FALLOW FIELD)

1	2	3	4	5	6	7
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

AMOUNT OF CACO3 TO NEUTRALIZ

0.00E+00

Fig. 11. Print out of results.

7.1. An example of a scenario calculation

The table in Fig. 11 only shows zeros. This is because all data are not yet available.

To give an impression of the type of results one may obtain with the model a simple scenario is set up.

The scenario is somewhat simular to the one used to illustrate calculations of the dispersion model. The geographical area is Zealand. The sources are the actual power plants on Zealand as shown in Fig. 11. Emissions are taken to be SO_2, NO_x, and Cd. Emissions of SO_2 and NO_x are the same as the ones used in the previous dispersion scenario, while emission of Cd is an estimate based on measurements for the Danish power station Studstrup (Miljøstyrelsen, 1980). Thus the emissions of Cd are not correct, but serve alone to illustrate the use of the model.

In addition to input of Cd to the soil from power plants, Cd is added to the soil by rain and the use of fertilizers. Rain is assumed to carry $1.3 \cdot 10^{-9}$ Mol/l Cd and fertilizers adds $2.4 \cdot 10^{-6}$ Mol/m^2 soil once a year. The amount of rain is taken from meteorological data for the area. Again these figures are thought to be sufficiently characteristic to give illustrative results.

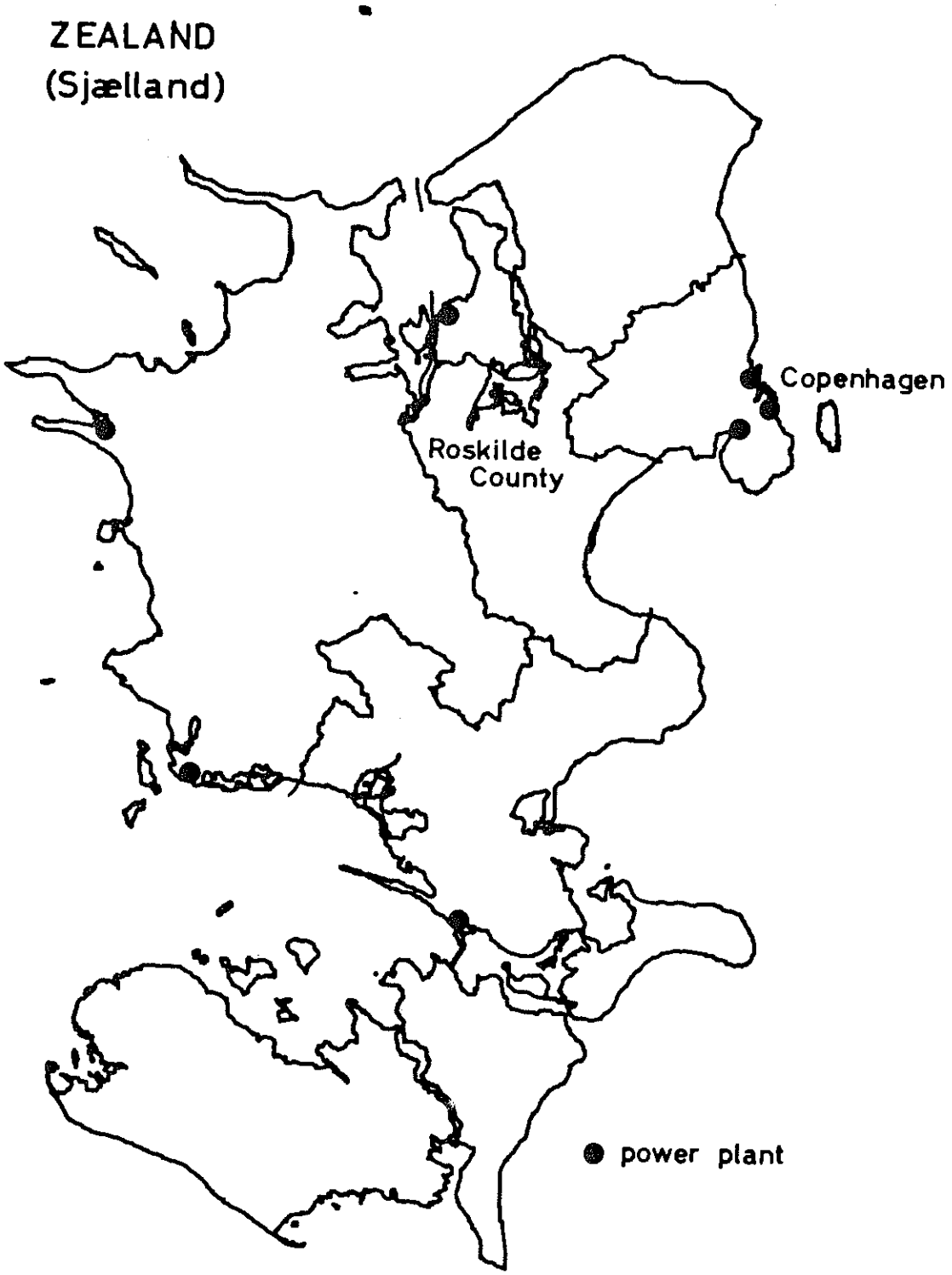

Fig. 12. Geographical area for scenario. County borders on Zealand shown.

In this scenario no lime is added to the soil.

The effects on the environment is shown as uptake of Cd in barley in a period of 15 years. The results are shown for barley grown on both a clay soil and sandy soil in Roskilde county (se Fig. 12). For both soil types the scenario has been run at first without the power plants. This gives the equilibrium background uptake of Cd^{++}. Then the scenario was run for both soil types for years and then emissions of the power plants were cut off. Fig. 13 shows the results.

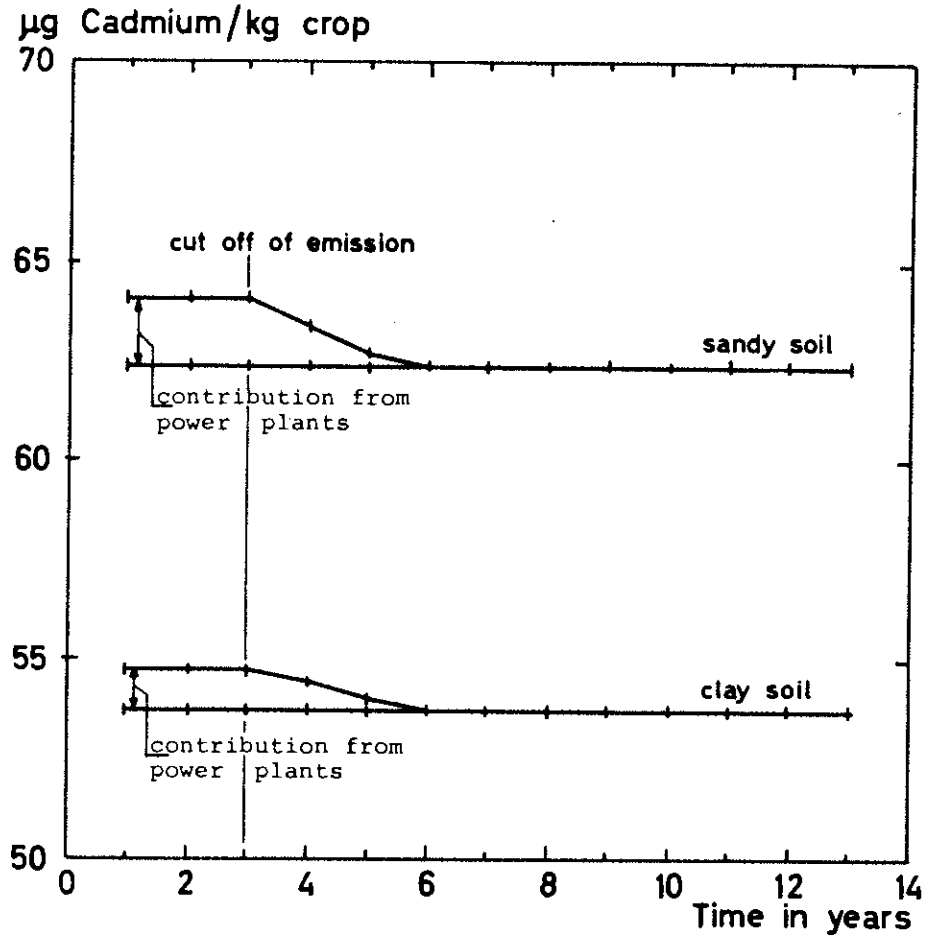

Figure 13. Cd uptake in barley from scenario calculation.

As expected, the uptake of Cd^{++} in barley when grown on a clay soil is lower than when grown on a sandy soil. This is due to the higher ion exchange capacity of the clay soil which will adsorb more Cd^{++}.

The transition shown when the emission from the power plants are cut off takes 4-5 years.

Note that the contribution of Cd^{++} uptake from power plants is small compared to the contribution from background rain and fertilizers. One should remember that the data used here is not correct. However, it is expected that power plants shall not contribute much to Cd^{++} uptake in crops.

8. FUTURE WORK

It is apparent that the model needs to be extended in many respects before the final goal has been achieved. The extentions which at the moment seem to be of most interest are a model to simulate impacts on forest systems (as an extension of the soil chemistry crop model), a model for aquatic systems and a model to calculate consumption of crops so as to calculate doses received by man via intake of food. This last model should be based on statistical information for use of crops. These tasks will be undertaken in the future.

However, the most immediate need is to collect data and to make estimates of uncertainties which one may expect in relation to the models. Along with refining the models already developed this task is expected to occupy the next year of the project.

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DEVELOPMENT OF THE PROGRAM SYSTEM ECCES FOR CALCULATING ENVIRONMENTAL CONSEQUENCES FROM ENERGY SYSTEMS
STATUS REPORT

Torben Petersen

Date 4.9.1984.

Department or group

Energy Technology

Group's own registration number(s)

MIL-8-84

pages + tables + illustrations

Abstract

This report describes the status of the development of the ECCES program system. The ECCES system is intended to predict environmental impacts from a given energy production scenario in a given geographical area.

Presently ECCES can follow transport and transformation of selected airborne pollutants (Cd, SO_2, NO_x) from sources via dispersion in the atmosphere and deposition on the ground to uptake in selected crops.

The ECCES system contains submodels for dispersion and deposition, soil chemistry, and uptake of ions in crops. These models are summarized in the present report and a few examples of calculations are shown.

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